Table 55. Pooled Observations on Four Contaminants

OBS	CONC10	WELL	X	Y	Z	TIME	MONTH	YEAR
1	0	GARRETT	300	750	30	0	12	79
2	2	AC2	4850	-1850	82	240	8	80
3	3	JOHNSON	400	900	35	240	8	80
4	11	HALL	625	1500	30	330	11	80
5	17	C9	3275	650	96	690	10	81
6	20	JOHNSON	400	900	35	120	4	80
7	43	AMBRUS	2000	0	30	360	12	80
8	270	C5C	1875	450	55	750	12	81
9	470	EPA6	2325	450	55	360	12	80
10	700	EPA6	2325	450	55	750	12	81
11	22900	DEP2	300	-50	25	120	4	80
12	128500	EPA1A	1375	550	41	240	8	80
13	270000	EPA1A	1375	550	41	750	12	81

CHEMICAL 4   BENZENE

OBS	CONC4	WELL	X	Y	Z	TIME	MONTH	YEAR
1	0.13	GARRETT	300	750	30	0	12	79
2	6.90	EPA7	1400	-650	42	390	1	81
3	16.00	JOHNSON	400	900	35	240	8	80
4	22.00	C6	1400	1175	100	750	12	81
5	26.00	JOHNSON	400	900	35	120	4	80
6	28.00	EPA6	2325	450	55	750	12	81
7	48.00	JOHNSON2	400	900	35	330	11	80
8	54.00	EPA5A	1450	1150	23	120	4	80
9	70.00	DEP3	1000	75	15	120	4	80
10	1800.00	EPA1A	1375	550	41	750	12	81
11	7900.00	EPA1A	1375	550	41	240	8	80

CHEMICAL 7   (MONO)CHLOROBENZENE

OBS	CONC7	WELL	X	Y	Z	TIME	MONTH	YEAR
1	0.2	EPA2	1400	-650	42	390	1	81
2	27.0	EPA1A	1375	550	41	240	3	80
3	27.0	EPA1A	1375	550	41	750	12	81
4	450.0	DEP2	300	-50	25	120	4	80

CHEMICAL 8   (1,2,4)-TETRACHLOROBENZENE

OBS	CONC8	WELL	X	Y	Z	TIME	MONTH	YEAR
1	17	DEP2	300	-50	25	120	4	80

Table 56. Summary of Guidelines and Standards for Health-Based Water Quality Levels

Compound or Chemical Class	EPA Code No.	NIOSH[a] Registry No.	Standard $\mu g/l$[b]	Notes
Acenaphthene	1B		20	(1)
Acrolein	2V		320	
Acrylonitrile	3V		0.58	(2)
Aldrin	89P		0.74n[c]	(2)
Antimony	114M		146	
Arsenic	115M		0.022	(2)
Asbestos	116M		3×10^5 fibers/l	(2)
Benzene	4V	CY1400000	6.6/2.3	(2),(11)
Benzidine	5B		0.0012	(2)
Beryllium	117M		0.37n	(2)
Cadmium	118M		10	(3)
Carbon Tetrachloride	6V	FG4900000	4/5.5	(2),(11)
Chlordane	91P		0.0046	(2)
Chlorinated Benzenes				
Hexachlorobenzene	9B		0.0072	(2)
1,2,3,5-tetra chlorobenzene			38	
pentachlorobenzene			74	
(1,2,4)-trichlorobenzene	8B		n.c.[d]	
(mono)chlorobenzene	7V		488/20	(4)
Chlorinated Ethanes				
1,2-di-chloroethane	10V	KI0525000	9.4/9.1	(2),(11)

continued...

Table 56. (continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/l	Notes
1,1,1-trichloroethane	11V	KJ2975000	18.4	
1,1,2-trichloroethane	14V	KJ3150000	6/6	(2),(11)
1,1,2,2-trichloroethane	15V		1.7	(2)
hexachloroethane	12B		19	(2)
mono(chloroethane)	16V		n.c.	
1,1-dichloroethane	13V	KI0175000	0.066	(2),(11)
1,1,1,2-tetrachloroethane			n.c.	
pentachloroethane			n.c.	
Chlorinated Napthalenes				
2-chloronapthalene	20B		n.c.	
Chlorinated Phenols				
monochlorophenol			0.1	(1)
4-monochlorophenol			0.1	(1)
2,3-dichlorophenol			0.04	(1)
2,5-dichlorophenol			0.5	(1)
2,6-dichorophenol			0.2	(1)
3,4-dichlorophenol			0.3	(1)
2,3,4,6-tetrachlorophenol			1	(1)
2,4,5-trichlorophenol			2600	(4)
2,4,6-trichlorophenol	21A		12/2	(2),(4)
2-methyl-4-chlorophenol			1800	
3-methyl-4-chlorophenol			3000	

Table 56.   (continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/l	Notes
3-methyl-6-chlorophenol			20	
p-chloro-m-cresol (parachlorometa cresol)	22A	GO7100000		
Chlorophenoxys (herbicides)				
2,4-D		AG6825000	100	(9)
2,4,5-TP Silvex		UF8225000	10	(9)
Chloroalkyl Ethers				
bis(chloromethyl) ether	17V	KN1575000	0.38n	(2)
bis(2-chloroethyl) ether	18B	KN0875000	0.3	(2)
bis(2-chloroisopropyl) ether		KN1750000	34.7	
2-chloroethylvinyl ether	19V	KN6300000		
Chloroform (trichloromethane)	23V	FS9100000	1.9/2.4	(2),(10),(11)
2-chlorophenol	24A		0.1	(1)
Chromium	119M		50	(3)
Copper	120M		1000	(1)
Cyanide	121M·		200	(3)
DDT and Metabolites				
4,4´-DDT	92P		0.24n	(2)
4,4´-DDE	93P			
4,4´-DDD	94P			
Dichlorobenzenes				
1,2-dichlorobenzene	25B			
1,3-dichlorobenzene	26B		400	
1,4-dichlorobenene	27B			

Table 56.　(continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/1	Notes
3-3´-dichlorobenzidine	28B		0.103	(2)
Dieldrin	90P		0.71n	(2)
Dichloroethylenes				
1,1-dichloroethylene"	29V	KV9275000	0.33	(2)
1,2-(trans)-dichloroethylene	30V	KV9360000	n.c.	
2,4-Dichlorophenol	31A		3090/0.3	(4)
(1,2)-Dichloropropane	32V		n.c.	
(1,3)-Dichloropropene (1,3-dichloropropylene)	33V		87	
2,4-Dimethylphenol	34A		400	(1)
2,4-Dinitrotoluene	35B		1.1	(2)
2,6-Dinitrotoluene	36B			
1,2-Diphenylhydrazine	37B		0.422	(2)
α-Endosulfan	95P		} 74	
β-Endosulfan	96P			
Endosulfan sulfate	97P			
Endrin	98P		1	(3)
Endrin aldehyde	99P			
Ethylbenzene	38V		1400	
Fluroranthene	39B		42	
Haloethers				
4-chlorophenyl phenyl ether	40B		n.c.	
4-bromophenyl phenyl ether	41B		n.c.	

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Table 56. (continued)

Compound or Chemical Class	EPA Code. No.	NIOSH Registry No.	Standard $\mu g/l$	Notes
bis(2-chloroisopropyl) ether	42B		34.7	
bis(2-chloroethoxy) methane	43B		n.c.	
Halomethanes				
methylene chloride (dichloromethane)	44V	PA8050000		
methyl chloride (chloromethane)	45V	PA6300000		
methyl bromide (bromomethane)	46V	PA4900000		
bromoform (tribromomethane)	47V	PB5600000	1.9	(10)
dichlorobromomethane	48V	PA5310000		(10)
trichlorofluoromethane	49V	PA9180000		
dischlorodifluoromethane	50V	PA8200000		
chlorodibromomethane	51V	PA6360000		(10)
Heptachlor	100P		2.78n	(2)
Heptachlor epoxide	101P			
Hexachlorobutadiene	52B		4.47	(2)
Hexachlorocyclohexane (BHC)				
α-HCH	102P	GV3500000	92n/2.8	(2),(11)
β-HCH	103P	GV4550000	0.163	(2)
γ-HCH (lindane)	104P	GV4900000	0.186/4/0.71	(2),(5),(12)
δ-HCH	105P		n.c.	
ε-HCH			n.c.	
tech-HCH (mixed isomers)			0.123	(2)
Hexachlorocyclopentadiene	53B		206/1	(4)
Isophorone	54B		5200	

continued...

Table 56. (continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/l	Notes
Lead	122M		50	(3)
Mercury	123M		0.144/2	(5)
Methoxychlor		KJ3675000	100	(9)
Naphthalene	55B		n.c.	
Nickel	124M		13.4	
Nitrobenzene	56B		19800/30	(4)
Nitrophenols				
Mononitrophenol (2-nitrophenol)	57A	SM2100000	n.c.	
4-Nitrophenol (p-nitrophenol)	58A	SM2275000		
Dinitrophenol		SL2625000	70	
2,4-Dinitrophenol	59A	SL2800000		
4,6-Dinitro-o-cresol				
(1,3,5 or 2,4,6)-Trinitrophenol		TJ7875000	n.c.	
4,6(2,4)-Dinitro-o-cresol	60A	GO9625000	13.4	
Nitrosamines				
N-nitrosodimethylamine	61B	IQ0525000	0.014	(2)
N-nitrosodiphenylamine	62B	JJ9800000	49	(2)
N-nitrosodi-n-propylamine	63B	JL9700000		
N-nitrosodiethylamine		IA3500000	8n	(2)
N-nitrosodi-n-butylamine		EJ4025000	0.064	(2)
N-nitrosopyrrolidine		UY1575000	0.160	(2)
Pentachlorophenol	64A		1010/30	(4)
Phenol	65A		3500/300	(4)

Table 56. (continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/l	Notes
Phthalate Esters				
bis(2-ethyl) phthalate	66B	TI0350000	15000	
butyl benzyl phthalate	67B	TH9990000		
di-n-butyl phthalate	68B	TI0875000	3400	
di-n-octyl phthalate	69B	TI9250000		
diethyl phthalate	70B	TI1050000	350000	
dimethyl phthalate	71B	TI1575000	313000	
Polychorinated Biphenyls (PCBs)				
PCB-1242	106B			
PCB-1245	107P			
PCB-1221	108P			
PCB-1231	109P		0.79n	(2)
PCB-1248	110P			
PCB-1260	111P			
PCB-1016	112P			
Polynuclear Aromatic Hydrocarbons (PAHs)				
benzo(a)anthracene	72B			
benzo(a)pyrene	73B			
3,4-benzofluoranthene	74B			
benzo(k)fluoranthene	75B		0.028	(2)
chrysene	76B			
acenaphthylene	77B			
anthracene	78B			

Table 56. (continued)

Compound or Chemical Class	EPA Code No.	NIOSH Registry No.	Standard µg/l	Notes
benzo(ghi)perylene	79B			
fluorene	80B			
phenanthrene	81B			
dibenzo(a,h)pyrene	82B		0.0^{28}	(2)
indeno(1,2,3-cd)pyrene	83B			
pyrene	84B			
Selenium	125M		10	(3)
Silver	126M		50	(3)
Tetrachloroethylene (PCE)	85V	KX3850000	8/11	(2),(11)
Thallium	127M		13	
Tolluene	86V		14300	
Toxaphene	113P		7.1n/5	(2),(5)
Trichloroethylene (TCE)	87V	KX4550000	27/33	(2),(11)
Vinyl Chloride	88V	KU9625000	20/2.4	(2),(11)
Zinc	128M		5000	(1)
Dioxin(2,3,7,8-tetrachlorodibenzo-p-dioxin)	129B			
Barium	131[e]		1000	(6)
Boron	132		750	(7)
Iron				

[a] National Institute for Occupational Safety and Health. 1979 Registry of Toxic Effects of Chemical Substances, (Cincinnati, Ohio, 1980).

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Table 56. (continued)

[b] All units in g/l (p.p.b.) unless indicated otherwise.

[c] Nanograms/liter (parts per trillion).

[d] No satisfactory criterion could be derived by EPA on the basis of available data.

[e] 131-143 are arbitrary code numbers, not EPA's.

Notes:

All standards apply to ambient water quality and, except as noted below, relate to the protection of human health from the toxic properties of the substance when ingested through water, except as noted.

For carcinogens, extrapolation of cancer responses from high to low doses and subsequent risk estimation from animal data was performed, using the linearized multi-stage model.

For noncarcinogens, the health criteria was based on concentrations which are not expected to produce adverse effects in humans.

All quality levels marked with notes (1) through (4) are guidelines under Section 304(a)(1) of the Clean Water Act (Source: EPA; Water Quality Criteria Document: Availability. Federal Register 45:231, 11/28/80).

A blank in the EPA code column implies that the specific compound is not on EPA's original list of 129 Priority Pollutants (House Committee on Public Works and Transportation. Hearings on the Implementation of the Federal Water Pollution Control Act, 95th Congress, 1st Session, July 1977, pp. 402-405). However, a water quality standard was assigned to that compound in the November 28, 1980 Federal Register's Notice.

A blank in the standard column indicates that the compound is not mentioned in the Notice, but is listed among the 129 Priority Pollutants (and tested for in laboratory analyses of polluted water).

(1) Standard based on organoleptic data. Indicated level is for controlling undesirable taste and odor quality of ambient water. These data have no demonstrated relationship to potential adverse human health effects.

(2) Maximum protection of human health (nonthreshold assumption) from potential carcinogenic effects requires zero concentration. The indicated level is based on the assumption that a zero level is presently unattainable. The indicated concentration to the lower 95% confidence limit producing an incremental increase of lifetime cancer risk of 10^{-5} (1 additional case in a population of 100,000). In the original document, simple linear extrapolation to 10^{-6} and 10^{-7} risk levels are given (divide the indicated concentration by 10 and 100, respectively).

(3) The calculated value is comparable to the present standard (the "Red Book").

(4) The second value is based on organoleptic data.

(5) The second value is a Maximum Contaminant Level (MCL) set forth in the National Interim Primary Drinking Water Regulations (Federal Register, August 27, 1980).

(6) A MCL standard (see note 5).

Table 56. (continued)

(7) This standard is set forth in EPA, Quality Criteria for Water, July 1976 ("Red Book"). It concerns long-term irrigation on sensitive crops, and is not a public health standard.

(8) A "Red Book" standard (see note 7) for domestic water supplies, based on "welfare" considerations which is a broader and probably less stringent category than health.

(9) A MCL has been determined for this compound (seen note 5), although it is not listed among the 129 Priority Pollutants.

(10) A MCL of 0.10mg/l has been set (see note 5) for total trihalomethanes (TTHMs). It applies only to community water systems which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in the treatment process. THMs group includes dichlorobromomethane (48V), bromoform (47V), chlorodibromomethane (51V), and chloroform (23V).

(11) The second value is from Crump, K. S. and H. A. Guess, Drinking Water and Cancer: Review of Recent Findings and Assessment of Risks. Science Research System, Inc., Ruston, La., 1980. It does not take into consideration exposure due to the intake of aquatic species.

APPENDIX D

CHEMICAL CONTROL CASE STUDY DATA APPENDIX

INTRODUCTION

This appendix assembles the data required for modeling the Chemical Control incident. Data on releases from the fire, meteorology of the area, and the population-at-risk are described in the following sections.

RELEASES

Chapter 7 discusses the inherent limitations associated with modeling releases based on the combustion process. An alternative was postulated, and the associated assumptions were outlined.

METEOROLOGY

Meteorological data was obtained from the National Climatic Center (Asheville, North Carolina, U.S. Department of Commerce, National Oceanic and Atmospheric Administration). The National Climatic Center collects meteorological data from the Newark, New Jersey, airport located about five kilometers northeast of Elizabeth. Because Newark is very close to the Chemical Control site in Elizabeth, we assume that meteorological conditions at the two places are similar. Measurements of wind speed and direction, sky cover, ceiling, weather, and temperature are taken on an hourly basis, and the National Climatic Center then compiles data on a three-hourly basis.

The data on wind direction and wind speed are directly applicable to our model. The sky cover and ceiling variables are necessary to construct stability variables. In the model, we used the 1980 data taken from observations rather than available ten-year averaged data, because the former retained information on sequences. In addition to the tabular data, we have obtained a National Climatic Center tape with data from various years, including computed stability factors.

The Turner stability class algorithm (tables 57, 58, and 59) is a procedure for constructing stability class variables based on time of day, cloud cover, ceiling, wind speed, and solar altitude. Solar altitude as a function of latitude and declination can be determined from the formulas summarized in table 60. Declination of the sun as a function of date is given in table 61. Duration of daylight is given in table 62 (Smithsonian Meteorological Tables, 1951).

Table 57. D. Bruce Turner Algorithm for Computing Stability Classes

I. Compute Net Radiation Index:

1. If the total cloud cover is 10/10 and the ceiling is less than
    7,000 feet, use net radiation index equal to 0 (whether day or
    night).

2. For nighttime (night is defined as the period from one hour before
    sunset to one hour after sunrise):

    a. If total cloud cover $\leq$ 4/10, use net radiation index equal to
        -2.

    b. If total cloud cover > 4/10, use net radiation index equal to
        -1.

3. For daytime:

    a. Determine the insolation class number as a function of solar
       altitude from table 58.

    b. If total cloud cover $\leq$ 5/10, use the net radiation index in
        table 59 corresponding to the insolation class number.

    c. If cloud cover > 5/10, modify the insolation class number by
        following these six steps:

        (1) Ceiling > 7,000 feet, subtract 2.

        (2) Ceiling $\geq$ 7,000 feet, but < 16,000 feet, subtract 1.

        (3) Total cloud cover equal 10/10, subtract 1. (This will
            only apply to ceilings $\geq$ 7,000 feet since cases with 10/10
            coverage below 7,000 feet. are considered in item 1 above.

        (4) If insolation class number has not been modified by steps
            (1), (2), or (3) above, assume modified class number equal
            to insolation class number.

        (5) If modified insolation class number is less than 1, let it
            equal 1.

        (6) Use the net radiation index in table 59 to the modified
            insolation class number.

Table 58. Insolation as a Function of Solar Altitude

Solar Altitude (a)	Insolation	Insolation Class Number
$60° < a$	Strong	4
$35° < a \leq 60°$	Moderate	3
$15° < a \leq 35°$	Slight	2
$a \leq 15°$	Weak	1

Table 59. Stability Class as a Function of Net Radiation and Wind Speed

Wind Speed (Knots)	Net Radiation Table						
	4	3	2	1	0	-1	-2
0,1	A	A	B	C	D	F	F
2,3	A	B	B	C	D	F	F
4,5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8,9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
12	C	D	D	D	D	D	D

Key: A: extremely unstable   D: neutral
      B: moderately unstable   E: slightly stable
      C: slightly unstable   F: moderately stable

Source: D. B. Turner, "A Diffusion Model for an Urban Area,"
         Journal of Applied Meteorology, vol 3, p. 91.

Table 60. Solar Altitude and Azimuth

$$\sin a = \sin \phi \, \sin \delta + \cos \phi \, \cos \delta \, \cos h$$

$$\sin \alpha = \cos \delta \, \sin h / \cos a$$

a = altitude of the sun (angular elevation above the horizon)

ϕ = latitude of the observer

δ = declination of the sun

h = hour angle of sun (angular distance from the emridian of the observer)

α = azimuth of the sun (measured eastward from north)

Table 61.

TABLE 169

EPHEMERIS OF THE SUN[1]

All data are for 0ʰ Greenwich Civil Time in the year 1950. Variations of these data from year to year are negligible for most meteorological purposes, the largest variation occurs through the 4-year leap-year cycle. The year 1950 was selected to represent a mean condition this cycle.

The declination of the sun is its angular distance north (+) or south (−) of the celestial equator.

The longitude of the sun is the angular distance of the meridian of sun from the vernal equinox (mean equinox of 1950.0) measured eastward along the ecliptic.

The equation of time (apparent − mean) is the correction to be applied to mean solar time in order to obtain apparent (true) solar time.

The radius vector of the earth is the distance from the center of the earth to the center of the sun expressed in terms of the length of the semimajor axis of the earth's orbit.

[1] U. S. Naval Observatory, The American ephemeris and nautical almanac for the year 1950, Washington, D.C.

EPHEMERIS OF THE SUN

Date	Decli- nation	Longi- tude	Equation of time	Radius vector	Date	Decli- nation	Longi- tude	Equation of time	Radius vector
	° ′	° ′	m. s.			° ′	° ′	m. s.	
Jan. 1	−23 4	280 1	− 3 14	0.98324	Feb. 1	−17 19	311 34	−13 34	0.98533
5	22 43	284 5	5 6	.98324	5	16 10	315 37	14 2	.98593
9	22 13	288 10	6 50	.98313	9	14 55	319 40	14 17	.98662
13	21 37	292 14	8 27	.98352	13	13 37	323 43	14 20	.98738
17	20 54	296 19	9 54	.98378	17	12 15	327 46	14 10	.98819
21	20 5	300 23	11 10	.98410	21	10 50	331 48	13 50	.98903
25	19 9	304 27	12 14	.98448	25	9 23	335 49	13 19	.98991
29	18 8	308 31	13 5	.98493					
Mar. 1	− 7 53	339 51	−12 38	0.99084	Apr. 1	+ 4 11	10 42	− 4 12	0.99928
5	6 21	343 51	11 48	.99182	5	5 46	14 39	3 1	1.00043
9	4 48	347 51	10 51	.99287	9	7 17	18 35	1 52	1.00160
13	3 14	351 51	9 49	.99396	13	8 46	22 30	− 0 47	1.00276
17	1 39	355 50	8 42	.99508	17	10 12	26 25	+ 0 13	1.00390
21	− 0 5	359 49	7 32	.99619	21	11 35	30 20	1 6	1.00500
25	+ 1 20	3 47	6 20	.99731	25	12 56	34 14	1 53	1.00606
29	3 4	7 44	5 7	.99843	29	14 13	38 7	2 33	1.00708

(continued)

EPHEMERIS OF THE SUN

Date	Decli- nation	Longi- tude	Equation of time	Radius vector	Date	Decli- nation	Longi- tude	Equation of time	Radius vector
	° ′	° ′	m. s.			° ′	° ′	m. s.	
May 1	+14 50	40 4	+ 2 50	1.00759	June 1	+21 57	69 56	+ 2 27	1.01476
5	16 2	43 56	3 17	1.00859	5	22 28	73 46	1 49	1.01475
9	17 9	47 48	3 35	1.00957	9	22 52	77 36	1 6	1.01515
13	18 11	51 40	3 44	1.01051	13	23 10	81 25	+ 0 18	1.01554
17	19 9	55 32	3 44	1.01138	17	23 22	85 15	− 0 33	1.01602
21	20 2	59 23	3 34	1.01218	21	23 27	89 4	1 25	1.01638
25	20 49	63 14	3 16	1.01291	25	23 25	92 53	2 17	1.01642
29	21 30	67 4	2 51	1.01358	29	23 17	96 41	3 7	1.01652
July 1	+23 10	98 36	− 3 31	1.01667	Aug. 1	+18 14	128 11	− 6 17	1.01454
5	22 52	102 24	4 16	1.01671	5	17 12	132 0	5 59	1.01442
9	22 28	106 13	4 56	1.01669	9	16 6	135 50	5 33	1.01434
13	21 57	110 2	5 30	1.01659	13	14 55	139 41	4 57	1.01311
17	21 21	113 51	5 57	1.01639	17	13 41	143 31	4 12	1.01244
21	20 38	117 40	6 15	1.01610	21	12 23	147 22	3 19	1.01153
25	19 50	121 29	6 24	1.01573	25	11 2	151 14	2 18	1.01056
29	18 57	125 19	6 23	1.01530	29	9 39	155 5	1 10	1.00944
Sept. 1	+ 8 35	157 59	− 0 15	1.00917	Oct. 1	− 2 53	187 14	+10 1	1.00014
5	7 7	161 52	+ 1 2	1.00822	5	4 26	191 11	11 17	1.00073
9	5 37	165 45	2 22	1.00723	9	5 58	195 7	12 27	1.00258
13	4 6	169 38	3 45	1.00619	13	7 29	199 5	13 30	1.00474
17	2 34	173 32	5 10	1.00510	17	8 58	203 3	14 25	1.00659
21	+ 1 1	177 26	6 35	1.00397	21	10 25	207 1	15 10	1.00634
25	− 0 32	181 21	8 0	1.00283	25	11 50	211 0	15 46	1.00430
29	2 6	185 16	9 22	1.00170	29	13 12	214 59	16 10	1.00032
Nov. 1	−14 11	217 59	+16 21	0.99249	Dec. 1	−21 41	248 13	+11 16	0.98653
5	15 27	222 0	16 23	.99150	5	22 16	252 16	9 43	.98654
9	16 38	226 1	16 12	.99054	9	22 45	256 20	8 1	.98641
13	17 45	230 2	15 47	.98960	13	23 6	260 24	6 12	.98648
17	18 43	234 4	15 10	.98869	17	21 20	264 28	4 17	.98652
21	19 45	238 6	14 18	.98784	21	23 26	268 32	2 19	.98672
25	20 36	242 8	13 15	.98706	25	23 25	272 37	+ 0 20	.98584
29	21 21	246 11	11 59	.98636	29	23 17	276 41	− 1 39	.98524

Table 62.

DURATION OF DAYLIGHT, CIVIL TWILIGHT, AND ASTRONOMICAL TWILIGHT

Daylight is defined as the interval between sunrise and sunset. The latter are considered to occur when the upper edge of the disk of the sun appears to be exactly on the horizon with an unobstructed horizon and normal atmospheric refraction. It is assumed that the upper edge of the sun appears on the horizon when the true center of the sun's disk is 50' below the horizon, this corresponds to assuming a semidiameter of 16' and a constant refraction of 34'.

Civil twilight is defined as the interval between sunrise or sunset and the time when the true position of the center of the sun is 6° below the horizon, at which time stars and planets of the first magnitude are just visible and darkness forces the suspension of normal outdoor activities.

Astronomical twilight is defined as the interval between sunrise or sunset and the time when the true position of the center of the sun is 18° below the horizon, at which time stars of the sixth magnitude are visible near the zenith and generally there is no trace on the horizon of the twilight glow.

Tables 171-174 (including graphs) have been extracted from a publication of the Nautical Almanac Office.[1] The data were computed for longitude 90° W. for the year 1966; however, there will be no appreciable error in using these tables for other localities or for other years during the remainder of the twentieth century in determining the *duration* of daylight or twilight.

For latitudes greater than 65° the data are given in graphical form. At these higher latitudes the data become increasingly uncertain, small changes in atmospheric refraction can cause relatively large changes in the actual phenomena, as can small errors in latitude, and the graphs give a clearer picture of the phenomena. Where the graphs are difficult to read accurately the phenomenon itself is uncertain. These large uncertainties are inevitable consequences of the physical circumstances and are not due to the inadequacy of the graphs.

Tables 171-173 may be used for Southern Latitudes by entering the tables not with the actual date but with a date about 6 months earlier or later as given in Table 174.

For a historical summary of the various definitions of twilight and a description of associated phenomena see Kimball.[2] .

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[1] Tables of sunrise, sunset and twilight, Supplement to the American ephemeris, 1946, U. S. Naval Observatory, Washington, 1945.

[2] Kimball, Herbert H., Month. Weath. Rev., vol. 44, pp. 614-620, 1916.

Table 62. (continued)

TABLE 171 (CONTINUED)

DURATION OF DAYLIGHT

Day of month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Latitude 30° N.												
1	10 15	10 46	11 33	12 29	13 20	13 57	14 03	13 34	12 46	11 53	10 59	10 22
5	10 17	10 53	11 40	12 36	13 26	13 59	14 01	13 29	12 39	11 46	10 53	10 19
9	10 21	10 59	11 47	12 43	13 31	14 02	13 58	13 23	12 32	11 38	10 48	10 16
13	10 24	11 05	11 54	12 50	13 37	14 04	13 55	13 17	12 25	11 32	10 42	10 14
17	10 27	11 12	12 02	12 57	13 42	14 04	13 52	13 11	12 18	11 25	10 36	10 14
21	10 33	11 18	12 09	13 04	13 47	14 05	13 48	13 04	12 10	11 17	10 32	10 12
25	10 37	11 25	12 16	13 10	13 50	14 05	13 43	12 58	12 03	11 11	10 28	10 13
29	10 43	11 33	12 24	13 17	13 55	14 03	13 39	12 51	11 56	11 05	10 24	10 14
Latitude 35° N.												
1	09 51	10 30	11 26	12 34	13 35	14 21	14 29	13 54	12 55	11 50	10 45	10 09
5	09 53	10 37	11 34	12 42	13 43	14 25	14 27	13 47	12 47	11 41	10 37	09 55
9	09 57	10 45	11 44	12 52	13 50	14 27	14 24	13 40	12 38	11 32	10 31	09 52
13	10 02	10 53	11 52	13 00	13 57	14 30	14 19	13 33	12 29	11 24	10 24	09 50
17	10 06	11 01	12 01	13 08	14 03	14 30	14 16	13 25	12 21	11 16	10 18	09 48
21	10 11	11 08	12 09	13 16	14 09	14 31	14 10	13 13	12 12	11 07	10 11	09 48
25	10 17	11 17	12 19	13 24	14 14	14 31	14 05	13 09	12 03	11 00	10 06	09 48
29	10 25	11 26	12 27	13 32	14 19	14 29	13 59	13 01	11 54	10 51	10 01	09 50
Latitude 40° N.												
1	09 23	10 10	11 18	12 39	13 54	14 49	14 58	14 16	13 05	11 47	10 29	09 33
5	09 27	10 19	11 28	12 50	14 02	14 53	14 55	14 08	12 55	11 36	10 20	09 29
9	09 31	10 28	11 38	13 00	14 11	14 57	14 52	14 00	12 44	11 26	10 11	09 25
13	09 36	10 37	11 50	13 10	14 19	15 00	14 47	13 51	12 34	11 16	10 03	09 22
17	09 42	10 47	12 00	13 20	14 27	15 00	14 42	13 41	12 24	11 06	09 55	09 20
21	09 49	10 58	12 11	13 30	14 34	15 01	14 36	13 32	12 13	10 55	09 48	09 20
25	09 56	11 07	12 21	13 40	14 40	15 01	14 29	13 22	12 03	10 46	09 42	09 20
29	10 03	11 18	12 32	13 49	14 45	14 59	14 22	13 13	11 52	10 37	09 36	09 22
Latitude 42° N.												
1	09 11	10 02	11 14	12 42	14 02	15 02	15 11	14 25	13 09	11 45	10 22	09 22
5	09 15	10 11	11 26	12 53	14 12	15 07	15 09	14 17	12 58	11 34	10 13	09 17
9	09 19	10 21	11 36	13 04	14 21	15 10	15 04	14 08	12 48	11 24	10 03	09 13
13	09 24	10 31	11 48	13 16	14 29	15 12	14 59	13 59	12 36	11 12	09 54	09 10
17	09 31	10 41	12 00	13 26	14 37	15 14	14 54	13 49	12 25	11 02	09 46	09 08
21	09 39	10 52	12 11	13 37	14 45	15 15	14 48	13 33	12 45	10 51	09 38	09 07
25	09 46	11 03	12 23	13 47	14 52	15 15	14 40	13 28	12 03	10 40	09 30	09 08
29	09 55	11 14	12 34	13 57	14 57	15 13	14 32	13 17	11 52	10 29	09 24	09 09
Latitude 44° N.												
1	08 58	09 52	11 10	12 45	14 11	15 16	15 26	14 36	13 14	11 45	10 15	09 09
5	09 01	10 03	11 22	12 57	14 21	15 21	15 23	14 27	13 02	11 32	10 04	09 03
9	09 06	10 13	11 34	13 08	14 31	15 24	15 18	14 17	12 50	11 20	09 54	08 59
13	09 12	10 24	11 46	13 20	14 40	15 28	15 13	14 07	12 39	11 08	09 44	08 56
17	09 19	10 35	11 59	13 32	14 49	15 29	15 07	13 56	12 26	10 57	09 35	08 54
21	09 27	10 47	12 11	13 44	14 47	15 29	15 00	13 45	12 14	10 45	09 27	08 53
25	09 35	10 59	12 23	13 55	15 04	15 29	14 52	13 34	12 03	10 34	09 19	08 54
29	09 45	11 10	12 36	14 06	15 11	15 27	14 44	13 23	11 50	10 23	09 12	08 56
Latitude 46° N.												
1	08 43	09 42	11 06	12 47	14 21	15 30	15 41	14 48	13 19	11 43	10 07	08 56
5	08 47	09 53	11 20	13 00	14 31	15 35	15 38	14 37	13 06	11 30	09 55	08 49
9	08 53	10 05	11 32	13 14	14 42	15 40	15 34	14 27	12 54	11 18	09 44	08 45
13	09 00	10 17	11 46	13 26	14 52	15 42	15 27	14 15	12 41	11 04	09 34	08 42
17	09 07	10 29	11 58	13 38	15 01	15 44	15 21	14 05	12 23	10 52	09 24	08 40
21	09 15	10 42	12 12	13 51	15 10	15 45	15 13	13 53	12 15	10 39	09 15	08 38
25	09 25	10 53	12 25	14 03	15 18	15 45	15 04	13 41	12 02	10 27	09 06	08 39
29	09 35	11 06	12 38	14 14	15 25	15 43	14 56	13 29	11 50	10 15	08 59	08 40

(continued)

The parameters σ_y and σ_z required for the Gaussian transport equation can then be approximated, for each stability class, by the phenomenological relationship depicted in figures 22 and 23. Equations (D.1) and (D.2) show the functions used to approximate these standard deviations:

$$\sigma_y = a(S)x^{b(S)} \qquad (D.1)$$

$$\sigma_z = c(S)x^{c(S)} \qquad (D.2)$$

where a(S), b(S), C(S), d(S) are functions of stability class S, derived in the U.S. EPA Climatological Dispersion Model (Busse and Zimmerman in User's Guide to the Texas Episodes Model). Parameter values appear in tables 64 and 65. The σ_v and σ_z curves were determined for an open, level to gently rolling terrain, and must therefore be adjusted for urban areas. The adjustment was made according to the method used in the Texas Episodes Model; dispersion coefficients were estimated by decreasing the stability class index by one except for class A (Texas Air Control Board, 1979).

POPULATION AT RISK

Populations of cities and counties in the area at risk is available from the 1980 Census of Population (U.S. Department of Commerce, Bureau of the Census, Numbers of Inhabitants). From the population data and the maps of cities and counties, we can develop a population density grid of the area surrounding Elizabeth. Table 25 and figure 19 define the density grid by township for an area of 442 km^2 (21 km x 21 km).

Figure 22. Variation of σ_y as a Function of Downwind Existence from a Source
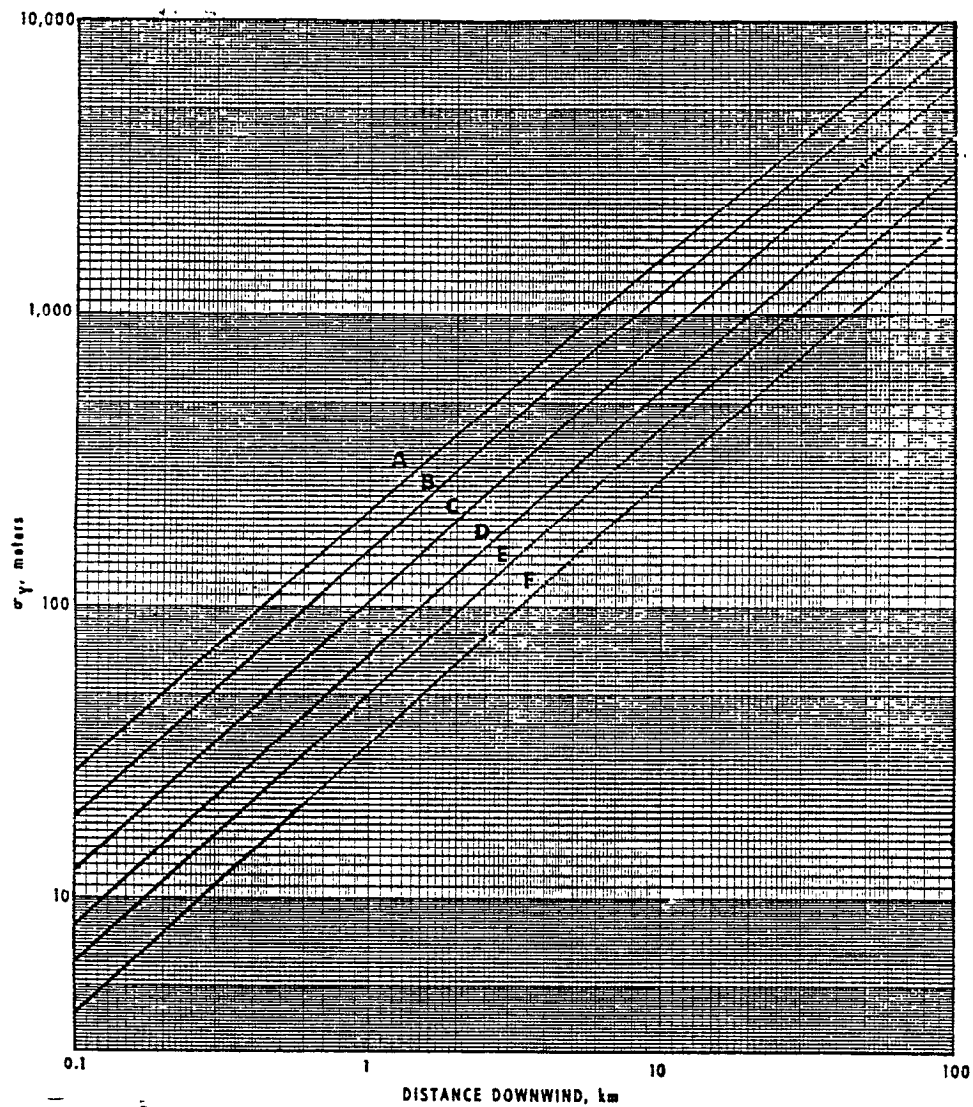
Source: D. B. Turner. 1964. "A Diffusion Model for an Urban Area," <u>Journal of Applied Meteorology</u> vol. 3, p. 91.